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APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

WIRE BODY BASED WELDING REPRESENTATION

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Wire Body Based Welding Representation

BACKGROUND

Advances in computing technology have made possible the provision of computer-aided-design (CAD) software to support the design and manufacturing of articles. Modern CAD software not only includes sketching or schematic features, but also solid modeling and other advanced features.

Manufacturing of articles often involves the welding of two or more components of an article into one single piece. A variety of welding types may be employed, including but are not limited to flange edge, butt, double flange, flange corner, single flange, square groove, square butt, and so forth. Accordingly, it is desirable for CAD software to support modeling of welding.

A few commercial CAD systems offer support for representing welds. Externally, the support includes highlighting and/or labeling of the edges of the components involved. However, the method in which this functionality is provided is proprietary, and not known. In particular, it is unknown whether the welds are separately modeled or represented, and if so, how they are modeled/represented.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will be described referencing the accompanying drawings in which like references denote similar elements, and in which:

Figure 1 illustrates a computing environment incorporated with one embodiment of the present invention;

Figures 2a-2b illustrate two examples of computing environments of **Fig. 1**;

Figure 3 illustrates an example machine readable article having instructions implementing all or portions of the CAD application of **Fig. 1**;

Figure 4 illustrates one embodiment of the operational flow of the weld bead modeling function of **Fig. 1**;

Figure 5 illustrates one embodiment of the operational flow of the persistent attribute assignment of a name operation of **Fig. 4**; and

Figures 6a-6d illustrate an example application of one embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Embodiments of the present invention include, but are not limited to, methods to model/represent welds in a computing environment, instructions implementing or contributing to the implementation of the methods, components, devices and systems incorporated with one or more implementations.

In the following description, various aspects of embodiments of the present invention will be described. However, it will be apparent to those skilled in the art that embodiments of the present invention may be practiced with only some or all aspects described. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of these embodiments of the present invention. However, it will be apparent to one skilled in the art that various embodiments of the present invention may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order not to obscure the disclosed embodiments of the present invention.

Various operations will be described as multiple discrete operations in turn, in a manner that is helpful in understanding these embodiments of the present invention, however, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations need not be performed in the order of presentation.

The phrase "in one embodiment" is used repeatedly. The phrase generally does not refer to the same embodiment, however, it may. The terms "comprising", "having" and "including" are synonymous, unless the context dictates otherwise.

Referring now to **Figure 1** wherein a computing environment incorporated with one embodiment of the present invention is illustrated. As shown, for the embodiment, computing environment **100** includes CAD application **112**, having associated user interface **102** and data representations **122**. CAD application **112** includes a number of CAD functions, in particular, weld bead modeling function **114** and shape manager **116**. The various CAD functions, including weld bead modeling function **114** and shape manager **116** are equipped to create, process and delete various data representations **122** of features of articles of manufacture, including in particular, data representations **126** of their components and edges, and data representations **128** of weld beads. Resultantly, articles of manufactures may be modeled **124**, and displayed **104** in user interface **102**, including their components, edges and weld beads, **106** and **108**.

Except for weld bead modeling function **114**, CAD application **112** including shape manager **116** represent a broad range of these elements, and may be implemented in a number of manners. For example, CAD application **112** may be implemented using the Inventor ® 7 (also referred to as Autodesk Inventor Series) mechanical design software product available from Autodesk Inc. of San Rafael, CA.

In alternate embodiments, CAD application **112** including shape manager **116** may be implemented with other CAD applications with an integral geometric modeler, or other CAD applications employing a complementary standalone geometric modeler instead.

Similarly, data representations **122** may be implemented in a variety of manners, including but are not limited to link lists, relational tables, data objects, and

other data organizations/structures of the like. Likewise, user interface **102** may be implemented in any one of a number of manners, in particular, a graphical manner.

Figure 2a illustrates one embodiment of computing environment **100** of **Fig. 1**. As illustrated, for the embodiment, computing environment **100** is a computing device **200** incorporated with one embodiment of the present invention. More specifically, computing device **200** includes processor **202**, memory **204**, mass storage device **206** and other I/O devices **208**, coupled to each other via bus **210**, as shown.

Memory **204** and mass storage device **206** include a transient working copy and a persistent copy of CAD application **112**, including associated user interface **102** and data representations **122** of **Fig. 1**. Further, for the embodiment, memory **204** and mass storage device **206** include a transient working copy and a persistent copy of operating system **222**, providing a number of system services to CAD application **112**.

Processor **202**, memory **204**, mass storage **206**, I/O devices **208**, and bus **210** represent a broad range of such elements.

In other words, except for CAD application **112** endowed with weld bead modeling function **114**, computing device **200** represent a broad range of such devices, including but are not limited to a server, a desktop computer, a computing tablet, a laptop computer, a palm sized personal assistant, a pocket PC, or other computing devices of the like.

Figure 2b illustrates another embodiment of computing environment **100** of **Fig. 1**. As illustrated, for the embodiment, computing environment **100** is a

networked computing environment **250** including client device **252** and server **256** coupled to each other via network **254**.

Collectively, client device **252** and server **256** are equipped with an embodiment of CAD application **112**, including associated user interface **102** and data representations **122**. In other words, CAD application **112**, including associated user interface **102** and data representations **122** are distributively disposed on client device **252** and server **256**. In various embodiments, client device **252** and server **256** may be computing device **200** of **Fig. 2a**.

Similarly, network **254** represents a broad range of local area, wide area, private and/or public networks. An example of a public network is the Internet.

Figure 3 illustrates a machine readable article suitable for use to store executable instructions implementing all or portions of the CAD application **112** of **Fig.1**, including weld bead modeling function **114**, in accordance with one embodiment. For the embodiment, the machine readable article includes storage medium **300** and instructions implementing all or portions of CAD application **112**, including weld bead modeling function **114**, stored therein. The stored instructions may be used to program an apparatus, such as computing device **200** of **Fig. 2a**, or client device **252** and/or server **254** of **Fig. 2b**.

In various embodiments, the instructions may be C or C++ programming language instructions or other system programming language instructions of the like. Further, storage medium **300** may be a diskette, a tape, a compact disk (CD), a digital versatile disk (DVD), a solid state storage devices, or other electrical, magnetic and/or optical storage devices of the like.

Figur 4 illustrates one embodiment of the operational flow of weld bead modeling function **114** of **Fig. 1**. The embodiment assumes CAD application **112** includes the functions for facilitating entry into a welding modeling mode of operation, where on entry, weld bead modeling function **114** is invoked. Further, CAD application **112** includes the functions for facilitating selection of the edges of the components of an article of manufacture involved in a particular welding operation to weld the components of the article together during manufacturing. For example, CAD application **112** may include support to facilitate a user in making the selection using a cursor control device, such as a mouse, trackball, a touch pad and so forth. The support may leverage user input device services provided e.g. by operating system **222**.

Continuing to refer on **Fig. 4**, as illustrated, on selection, weld bead modeling function **114** first assigns tracking attributes (AT) to the selected edges of the components of the article of manufacture, where welding is to be performed when manufacturing the article, block **402**.

In various embodiments, AT includes attributes specifying that the attributes are to be propagated whenever a split, copy or merge operation is performed on each of the selected edges. AT's split, copy and merge behaviors are specified such that, during a split or copy operation, which results in an old entity and a new entity, a copy of the attribute on the old entity propagates itself to the newly formed entity. During a merge operation of two entities, all the original attributes from the two entities are retained on the merged entity.

Further, in various embodiments, AT includes information that allows the split, copied or merged versions of the selected edges to be tracked back to the original selected edges. In various embodiments, AT includes a unique index, i, which is incremented for each of the selected edges processed.

Note that all operations, including any split, copy or merge operations, performed on an edge or other features of a component within computing environment **100**, in substance are performed on data representations **122** of the edge/feature of the component. For ease of understanding, further description may not be burdened with the repeated clarification. However, the description should be so read, unless the context clearly indicates otherwise.

Next, at block **404**, weld bead modeling function **114** copies the selected edges, replicating their data representations.

At block **406**. weld bead modeling function **114** causes a wire body (or more specifically, a data representation of a wire body) to be created for each selected edge. For the embodiment, weld bead modeling function **114** causes a wire body (or more specifically, a data representation of a wire body) to be created for each selected edge by calling shape manager **116** to perform the actual creation.

At block **408**, weld bead modeling function **114** determines for the instance weld to be modeled, whether there is one, or more than one wire body involved.

If more than one wire body is involved, then weld bead modeling function **114** further causes a combined wire body (more specifically, a combined data representation) to be formed, by uniting the one or more wire bodies (more specifically, their data representations) together, block **410**. For the embodiment,

weld bead modeling function **114** causes the combined wire body (or more specifically, a combined data representation of the combined wire body) to be created by calling shape manager **116** to perform the unite operation.

Upon either determining if, there is only one wire body involved or having merged all the wire bodies into a combined wire body, weld bead modeling function **114** initializes the data representation of this final wire body as the data representation or model of the wire bead, block **412**. The data representation or model of a "weld bead" is also referred to as "cosmetic weld bead" or "virtual weld bead". For the present application, including the claims, these terms are synonymous, unless the context clearly indicates to the contrary.

Upon initializing the final united wire body as the data representation of the weld being modeled, weld bead modeling function **114** creates various attributes to record the applicable weld parameters, based on user inputs, block **414**. The nature of the parameters is dependent on the type of the weldment. For example, in the case of a V Groove weld, the parameters may include a gap size, and an angle size between the applicable components.

Upon creating the welding parameter attributes, weld bead modeling function **114** causes each edge of the weld bead to be persistently named, block **416**. In various embodiments, persistent naming comprises persistent attribute assignment of a name to each edge.

Figure 5 illustrates one embodiment of the persistent attribute assignment of a name operation of **Fig. 4**. As illustrated, for the embodiment, weld bead modeling function **114** first selects an edge of the weld bead, block **502**. Then, weld bead

modeling function **114** retrieves the AT of the selected edge of the weld bead, block **504**. Next, using the AT, weld bead modeling function **114** locates the edges of the components that contributed to the selected edge of the weld bead, block **506**. Note that an edge of a weld bead may result from more than one selected edge of the components to be welded together.

At this point, weld bead modeling function **114** retrieves for each edge of the components involved, one or more identifications identifying the edge(s) and the component(s) to which the edge(s) is a part, block **508**. In various embodiments, two identifications, a component identification (C_{id}) and an edge identification (E_{id}), are retrieved for each selected edge.

Finally, weld bead modeling function **114** creates a persistent name attribute, block **510**, based on the retrieved one or more identifications identifying the edges, and the components to which the edges are a part.

Thus, by virtue of the employment of wire bodies, the data representation of a modeled weld bead under the disclosed embodiments of the present invention is light-weight. When compared to other approaches, e.g. a 3-D solid modeling approach, substantial efficiency gains may be realized. Moreover, the wire body representation, in essence, is a complete representation, as it captures the geometry, topology and all the weld parameters. Moreover, by virtue of the persistent naming, the data representation of a weld bead may be efficiently processed independent of the components' edges that result in corresponding edges in the wire body.

Further, the disclosed embodiments avoid the need to use complex shape generation algorithms that are used in the solid weld bead approach. When implemented using Autodesk Inventor, the disclosed embodiments comprise essentially two "actions", whereas a solid weld bead approach involves as many as six "actions".

Figure 6a-6d illustrate an example application of CAD application **112** having weld bead modeling function **114**. The example application assumes the manufacturing of an example article involves the welding of angle iron **602** to base plate **604** (see **Fig. 6a**).

Accordingly, CAD application **112** may be employed to first facilitate the selection, e.g. by a user, the edges of angle iron **602**, where the welding is to be performed. The selected edges are shown in **Fig. 6b** and **6c**.

In response, the operations of **Fig. 4-5** are performed, resulting in the creation of a wire body based data representation **606** of the weld (see **Fig. 6d**).

As illustrated, representation **606** is light-weight, and involves only 1 lump, 1 shell, 1 wire, 0 face, 0 loop, 9 co-edges, 9 edges and 9 vertices. In contrast, a comparable solid weld bead representation is likely to have 1 lump, 1 shell, 19 faces, 20 loops, 90 co-edges, 45 edges, and 27 vertices.

Thus, it can be seen from the above descriptions, embodiments of a novel method to represent welds have been described. While the novel method has been described in terms of the foregoing embodiments, those skilled in the art will recognize that the method is not limited to the embodiments described. The method

may be practiced with modifications and alterations within the spirit and scope of the appended claims.

Accordingly, the description is to be regarded as illustrative instead of restrictive.

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